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(71) Applicant: **ZENITH ELECTRONICS CORPORATION**
Zenith Center 1000 Milwaukee Avenue
Glenview Illinois 60025(US)

(72) Inventor: **Rabii, Khosro M.**
3827 Galena Court
Arlington Heights, Illinois 60004(US)

(74) Representative: **Baillie, Iain Cameron et al**
c/o Ladas & Parry Isartorplatz 5
D-8000 München 2(DE)

(54) Dynamic range video black level expander.

(57) A digital video signal black level expander in which the dynamic range of the video signal is the criterion for expansion. The digital video signal is compared pixel by pixel in maximum and minimum comparators (24, 26) and the maximum and minimum pixel values for each field are stored in latches (30, 34). Integrators (40, 42) average the maximum and minimum pixel values over successive pairs of fields of the video signal. The integrated minimum pixel value is subtracted from the integrated maximum pixel value to determine the dynamic range of the pixels in the video signal. A tilt-point pixel value is established as a function of the dynamic range, above which no expansion is permitted. Digital video signals below the tilt point (Xt) are expanded. Programmable constants (K1) are supplied to modify the dynamic range effect and the amount of expansion as desired. A low pass filter (22) removes high frequencies prior to comparing pixel values.

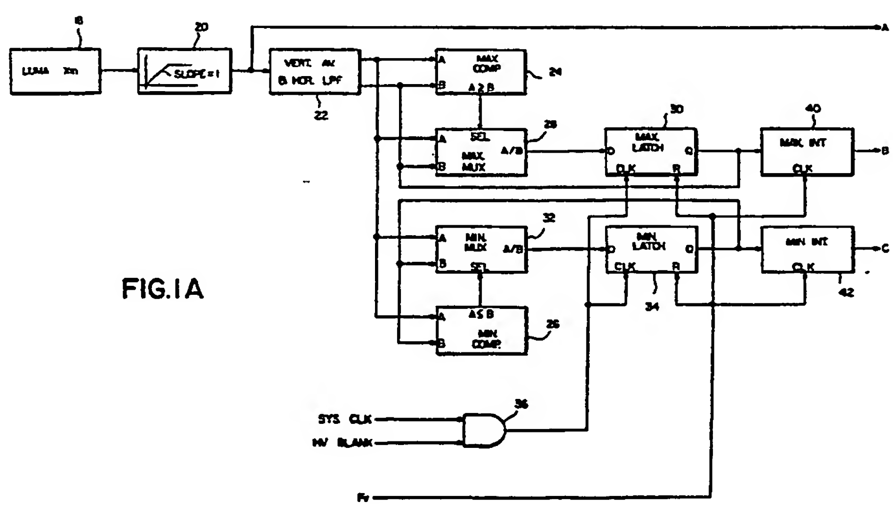

FIG.1A

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DYNAMIC RANGE VIDEO BLACK LEVEL EXPANDER

This invention relates in general to digital television systems and in particular to a black expander for a digital video signal in a digital television system.

In many reproduced televised scenes, the contrast may not be optimum and changing the setting of the receiver "contrast control" setting may not produce any improvement. While the optimum contrast of a particular scene is a matter of subjective judgment, circuits are being constructed to produce scenes of perceived optimum contrast. One prior art television receiver has a circuit for automatically expanding the portion of the video luminance signal that corresponds to grey areas of the picture, to make the picture elements in these areas darker. The resulting improvement in contrast, by expanding the grey areas, is considered to yield a beneficial result. That circuit is an analog implementation and operates by seeking out the blackest portion of the video signal and moving it toward, or fixing it at, the receiver black level. Other video signals between the blackest portion and an arbitrary "breakpoint" are proportionately expanded. Video signals above the breakpoint are not affected.

With the advent of digital television receivers, such analog techniques are not applicable. The present invention is directed to a black expander for a digital television receiver utilizing a method and apparatus for ascertaining the dynamic range of the digital video signal and thereafter using the dynamic range to determine black signal level expansion. In the absence of a dynamic range for the video signal, no black expansion is permitted even though the video signal is below the expansion tilt point.

The present invention therefore provides a method of processing a digital video signal comprising the steps of determining the dynamic range of said digital video signal, establishing a tilt-point digital video signal level as a function of said dynamic range, and expanding video signals that are below said tilt-point video signal level.

The present invention further provides a digital video signal black expander including means for determining the dynamic range of a video signal, means establishing a tilt-point video signal level as a function of said dynamic range, and means for expanding portions of said digital video signal that are below said tilt-point video signal level.

With the invention, black expansion is not performed except under conditions where doing so will provide a benefit to the viewer. The premise is that if the video signal has no dynamic range, or only limited dynamic range, there is no need for black expansion. Indeed, black expansion under uniform signal conditions may be detrimental to the video display. Preferably, the high frequencies in the luminance signal are removed prior to processing to eliminate rapid transitions which could create annoying flicker in the displayed video.

Further features and advantages of the invention will be apparent upon reading the disclosure of a preferred embodiment of the specification in conjunction with the drawings, in which:

FIGS. 1A and 1B when combined, are a partial block diagram of a video processor of the invention; and

FIG. 2 is a graph indicating operation of the video black expander of the invention.

Black level expansion in accordance with the invention is performed only when there is a dynamic range to the input digital video signal. The degree or amount of dynamic range determines the tilt point in a direct fashion such that the larger the dynamic range of the input signal the higher the tilt point. Specifically, with reference to FIG. 2 the tilt point Xt is calculated as the product of a programmable constant K1 and a factor D that represents the difference between Xmax and Xmin. Therefore, Xt equals (K1) D, where D is equal to Xmax -Xmin. Xmax and Xmin, in accordance with the invention, are integrated pixel values that are derived over successive fields of the video signal.

FIG. 1A and FIG. 1B should be positioned with arrows A, B and C in alignment. A source 18 of luminance (LUMA) signal input (Xin) comprises a series of pixels, each represented by 8 bits. The digitized input signal is supplied through a limiter 20 to a vertical average and horizontal low pass filter (LPF) 22 for removing high frequencies. The frequency range of low pass filter 22 is 0 to 1.2 MHz. The frequency limitation removes any rapid transitions in video from the black level expander processor. A practical implementation includes a three line delay with corresponding pixels from each line being averaged by the vertical LPF and supplied as an output to the horizontal LPF. While not essential, this averaging technique prevents misinterpretation of noise on a single line. The output of LPF 22 is coupled to the A inputs of each of a max comparator 24, a min comparator 26, a max multiplexer 28 and a min multiplexer 32. The output of max comparator 24 is applied to the SEL input of max multiplexer 28, the output of which is connected to the D input of a max latch 30.

It will be recognized that, while only a single latch is indicated for simplicity, there are actually eight latches, one corresponding to each bit of the signal Xin. The Q output of max latch 30 is coupled to the B inputs of max comparator 24 and max

multiplexer 28. The output of min comparator 26 is similarly coupled to the SEL input of min multiplexer 32, the output of which is connected to the D input of a min latch 34, of which there are also eight. The Q output of min latch 34 is connected to the B inputs of min comparator 26 and min multiplexer 32. Both latches 30 and 34 are clocked only during active video by a signal that is produced by an AND gate 36, the inputs to which are a pixel clock and a horizontal-vertical (HV) blanking signal. A field rate signal is coupled to the reset terminals of max latch 30 and min latch 34, thus resetting the latches for every field of video.

In operation, max latch 30 is reset at the beginning of each video field to all O's while min latch 34 is reset to all 1's. The O value or level of max latch 30 is compared with the value of the first pixel applied to the A input of max comparator 34, which is presumably greater than O. Comparator 24 therefore selects the A output of max multiplexer 28 so that the first pixel value is coupled to and stored in max latch 30. This process is repeated for each successive pair of pixels and results in a maximum pixel value being stored in max latch 30. A similar process is performed to derive the minimum pixel value, which is stored in min latch 34. Here again, the value or level of the first pixel applied to the A input of min comparator 26 will normally be less than the reset condition of all 1's for min latch 34. The result of the max and min comparisons is that the brightest video pixel and the darkest video pixel values for each video field are stored in max latch 30 and min latch 34, respectively. The output of max latch 30 is coupled to the input of a max integrator 40 and the output of min latch 34 is coupled to the input of a min integrator 42. The max and min integrators 40 and 42 are clocked at a field rate and receive the max and min values from max latch 30 and min latch 34 each field. Each integrator is arranged to add the new maximum (or minimum) pixel value from its respective latch to the existing level in the integrator and to divide the sum by two.

Assuming the max integrator is initially set to zero, the max pixel value (assumed to be 10) from max latch 30 would be added to zero and divided by two to establish the new pixel value of 5 in max integrator 40. In the next video field, the new max latch pixel value (assumed to be 13) is added to the max integrator pixel value of 5 and divided by two to establish a new pixel value of 9 for max integrator 40. The process is repeated for all pixels in the field. A similar process occurs with respect to the min integrator 42. The provision of the integrators effectively desensitizes the dynamic range calculation and precludes black expander operation in response to short term changes in video dynamic range.

The output of max integrator 40 is applied to the positive input of an adder 44 and the output of min integrator 42 is applied to the negative input of adder 44. Effectively, the value of the min integrator 42 output is subtracted from the value of the max integrator 40 output to produce a dynamic range value (D) at the output of adder 44. A multiplier 46 multiplies the dynamic range value D by a Factor K1, which is programmable as indicated by the arrow, labelled Xrange, adjacent to multiplier 46. This produces a value (K1) D. Constant K1 is programmable in 16 steps from 1/16 to 1. The output of min integrator 42 is also coupled to the A input of a comparator 48, the B input of which is supplied with a programmable limit value Xlimit. When the minimum value at the output of min integrator 42 is greater than or equal to the limit value Xlimit, comparator 48 develops an output for disabling the black expansion processing system by causing a switch 50 to assume an open position.

With switch 50 in its closed position as shown, the level (K1) D is supplied to the positive input of an adder 52. The value at the output of min integrator 42 is also supplied to a positive input of adder 52 which produces an output, Xt that is equal to (K1) D+Xmin. This value is applied to a negative input of another adder 54. Adder 54 receives, at its positive input, the original digital video signal Xin (from limiter 20). Thus Xt is subtracted from the original signal Xin and applied to another multiplier 56 having a programmable slope factor K2. Slope factor K2 is programmable in eight steps of 1/4 each between 7/4 and O as indicated by the adjacent arrow labelled Xslope. The output of adder 56 is therefore:

K2(Xin-Xt) = K2Xin-K2[K1(Xmax-Xmin) + Xmin].

This signal is applied to a limiter 58 having a break at tilt point Xt and an output that is characterized as follows:

If Xin is less than Xt, the output is K2(Xin-Xt).

If Xin is equal to or greater than Xt, the output is O.

The input signal Xin is added to the output of limiter 58 in another adder 60 which provides a processed output luminance signal after further conventional limiting in a limiter 62, characterized as follows:

If Xin is less than Xt, the output is K2(Xin-Xt) + Xin.

If Xin is equal to or greater than Xt, the output is Xin.

It is thus seen that for values of Xin that are greater than or equal to the tilt point Xt, the original response curve or transfer characteristic is followed. However, for values of Xin that are less than the tilt point Xt, the response curve is modified such that Xout = K2(Xin-Xt) + Xin. Since Xt = K1 times D + Xmin, the tilt point is a function of the dynamic range of the video signal.

With reference to FIG. 2, any value of Xin that is greater than or equal to 40 will follow curve 70 and produce an output Xout = Xin. For values of Xin less than 40, the response will follow curves having different slopes depending upon the value of the slope factor K2. For example, if K2 = 0, Xout will always equal Xin, that is, the response curve will be coincident with curve 70. If K2 = 1 and Xin = 20, then Xout = 0 as represented by the curve marked K2 = 1. If K2 = 7/4, then Xout would be 0 for all Xins up to approximately 24.

Consequently, with the invention, black level expansion is performed only when there is a dynamic range to the video signal. As noted above, the degree or amount of dynamic range determines the tilt point in a direct fashion such that the larger the dynamic range, the higher the tilt point. When the dynamic range D is zero, the tilt point Xt = Xmin, and no expansion occurs. Thus expansion of signals toward black is performed in accordance with the degree to which an apparent improvement in contrast will be most noticeable to the viewer. When the improvement would not be noticeable, i.e., where there is no dynamic range to the signal or where there is only a signal of minimal dynamic range, expansion is not performed (or only performed in a minimal amount). Consequently, with the invention, black expansion is performed under signal conditions where it may be of benefit to the viewer and not performed under other signal situations.

Claims

1. A method of processing a digital video signal comprising the steps of determining the dynamic range of said digital video signal, establishing a tilt-point digital video signal level as a function of said dynamic range, and expanding video signals that are below said tilt-point video signal level.

2. The method of claim 1, wherein said digital video signal is in pixel form and wherein said step of determining said dynamic range includes the steps of determining a maximum pixel value and a minimum pixel value for said digital video signal, and subtracting said minimum pixel value from said maximum pixel value.

3. The method of claim 2, including the steps of comparing successive pixels in each field of said digital video signal to determine the pixel of greatest value and the pixel of least value, storing said greatest and least values in respective maximum and minimum value latches, and integrating said maximum and minimum pixel values over a plurality of fields

4. The method of claim 3 includes the step of low pass filtering said digital video signal before said comparison step to eliminate high frequency components.

5. The method of any of claims 1 to 4, wherein a programmable constant is applied to modify the pixel value of said dynamic range preferably by expanding the video signals by a programming factor.

6. The method of claim 2, wherein the subtraction of said minimum pixel value from said maximum pixel value determines the dynamic pixel range of said video digital signal, said method including the step of supplying said digital video signal without expansion for signal portions above said tilt-point value, and expanding signal portions below said tilt-point value by a predetermined factor which is preferably adjustable to vary the amount of expansion.

7. The method of claim 6, including the steps of providing maximum and minimum latches for storing said maximum and minimum pixel values, resetting said latches for every field of said digital video signal, and integrating said maximum and minimum pixel values over a number of fields of said digital video signal.

8. A digital video signal black expander including means for determining the dynamic range of a video signal, means establishing a tilt-point video signal level as a function of said dynamic range, and means for expanding portions of said digital video signal that are below said tilt-point video signal level.

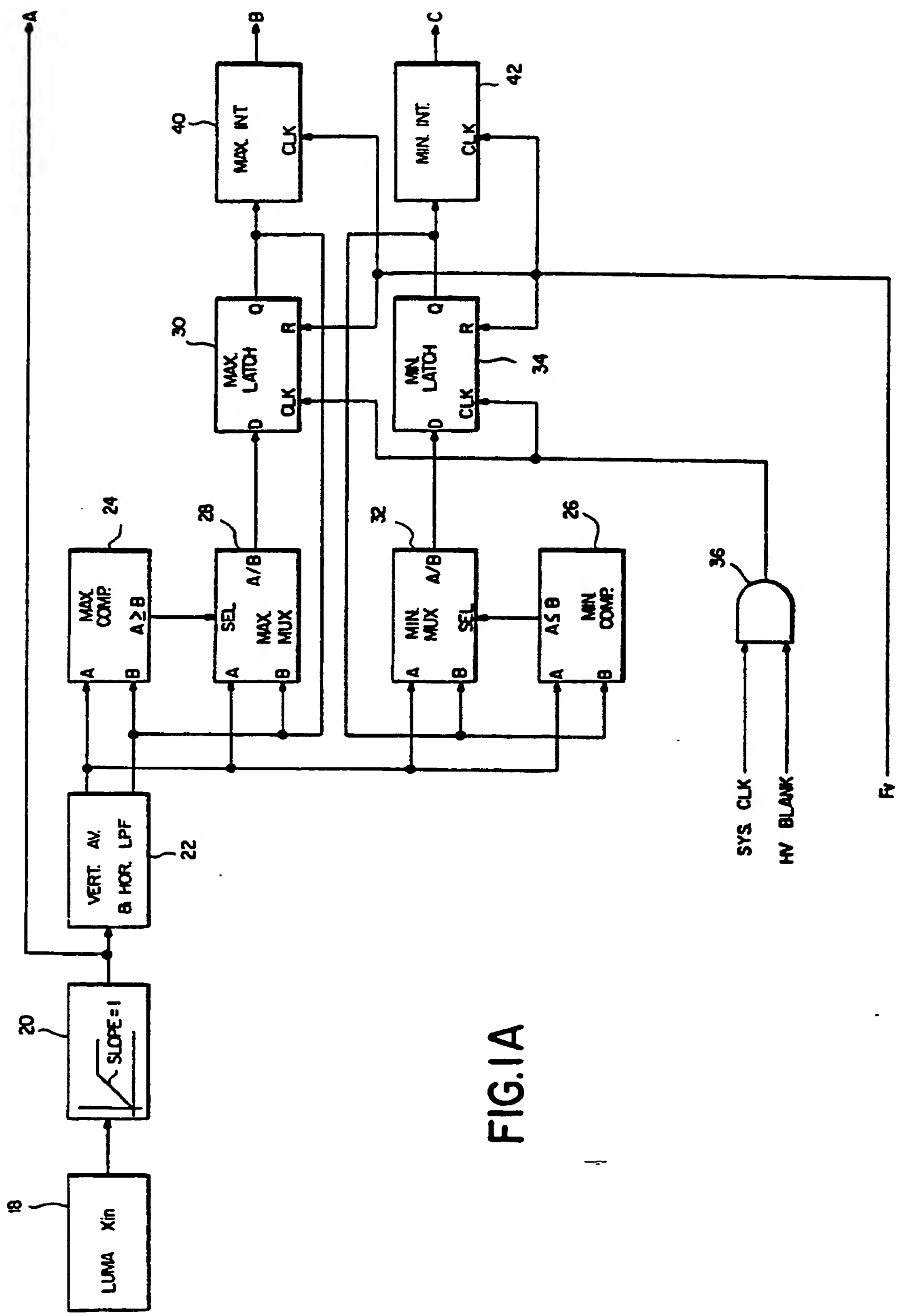
9. The expander of claim 8 wherein said digital video signal comprises a series of pixels and wherein said dynamic range determining means includes maximum and minimum comparison means for comparing the levels of successive pixels in said digital video signal and determining maximum and minimum pixel levels, and subtraction means for subtracting said minimum pixel level from said maximum pixel level.

10. The expander of claim 9, including low pass filter means for removing high frequencies from said digital video signal prior to supplying said digital video signal to said comparison means.

11. The expander of claim 9 or 10, including maximum and minimum latches for storing said maximum and minimum pixel levels, respectively, and integration means for averaging said maximum and minimum pixel levels over a plurality of fields of said digital video signal.

12. A digital video signal black expander including means including maximum and minimum comparison means for comparing successive pixels in said digital video signal and determining maximum and minimum pixel levels therein, maximum and minimum latches for storing said maximum and minimum pixel levels, integration means for

averaging said maximum and minimum pixel levels over a plurality of fields of said digital video signal, subtraction means for subtracting said integrated minimum pixel level from said integrated maximum pixel level to develop a dynamic range of said pixel levels in said digital video signal, means establishing a tilt-point level for said digital video signal pixels as a function of said dynamic range, and means for expanding portions of said digital video signal that are below said tilt-point level.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18
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D
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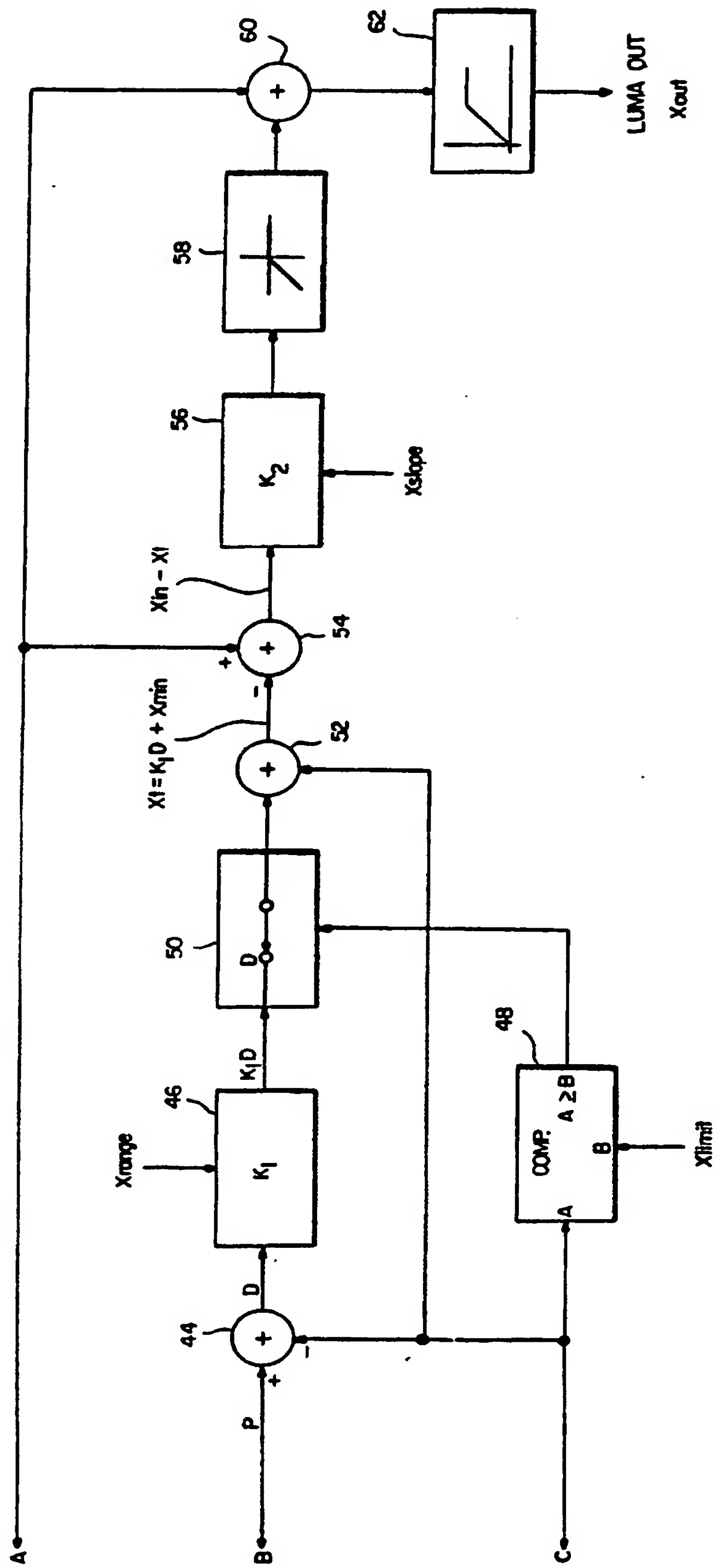
FIG.1A

FIG.1B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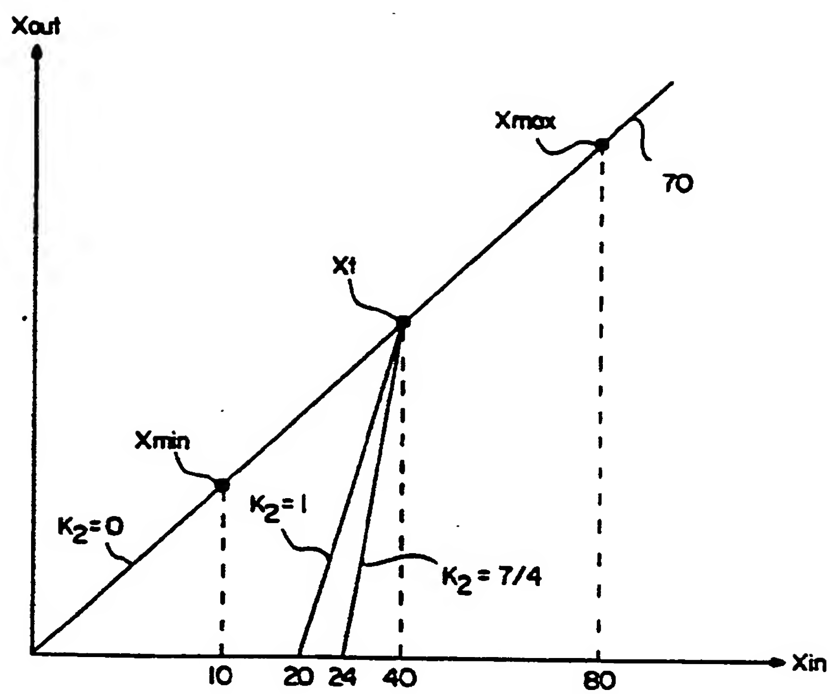

FIG.2

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EUROPEAN SEARCH REPORT

Application number

EP 90106088.9

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	DE - A1 - 3 714 861 (FRAUNHOFER) * Abstract; fig. 1 *	1,8,12	H 04 N 5/57 H 04 N 5/20
A	GB - A - 2 145 599 (SONY) * Abstract; fig. 5,6; page 2, line 124 - page 3, line 10 *	1,8	
A	GB - A - 2 010 634 (THOMSON-CSF)		

TECHNICAL FIELDS SEARCHED (Int Cl.5)

H 04 N 5/00
H 04 N 9/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	07-06-1990	BENISCHKA

CATEGORY OF CITED DOCUMENTS

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